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THE INTERNATIONAL ECONOMICS OF TRANSITIONAL GROWTH -- THE CASE OF THE UNITED STATES

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ABSTRACT

This paper develops a general equilibrium two country, two commodity dynamic simulation model of international trade in commodities and financial claims. The model generalizes the Heckscher-Ohlin static theory of trade by incorporating costs of quickly adjusting levels of capital stocks in particular industries; i.e., capital mobility in the short run is permitted, but at a price. The model predicts Heckscher-Ohlin relationships, including factor price equalization, in the long-run, but not during the economy's transition path to its ultimate steady-state. An interesting feature of the model is that it provides a determinate solution to the long-run international allocation of the world's capital stock. This is true despite the fact that the Rybchinski-theorem holds in the long-run.

The simulation model of international trade with costly capital stock adjustment appears capable of explaining many features of the patterns of factor price equalization, international investment, and changes in comparative advantage that have characterized the post-war period.

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The International Economics of Transitional Growth --

The Case of the United States

The poor absolute performance of the U.S. economy in the 1970's and the poor relative performance of the U.S. economy vis-a-vis those of Japan, Germany, and other Western European countries over the past three decades is today the object of intense public concern. Economic growth has emerged as the foremost goal of the new administration. The U.S. government has, itself, been identified as the major impediment to national growth and prosperity. While government regulation, bureaucracy, and taxation have surely played some role in U.S. economic stagnation, the poor absolute and relative performance of the U.S. economy in the post-war period is better understood to be the result of dramatic, but predictable changes in the international marketplace, changes that, for the most part, have been and continue to be beyond the control of anyone in the U.S.

The U.S. economy has been and is engaged in a process of international economic growth that may entail poor relative and, indeed, absolute economic performance for years to come. The United States emerged in 1945 with its industrial plant and equipment largely unaffected by the ravages of the second world war. In contrast the capital stocks of western European countries and Japan were largely destroyed. The lead thereby afforded the U.S. in capital per man has predictably, been shortened over time as major trading partners of the United States have accumulated capital at a much faster rate than the United States. In 1958 over 50 percent of the world's capital stock was situated in the United States. Today's figure is less than 35 percent.* For particular commodities, changes in

*Measured by accumulating gross domestic investment flows from 1948 and applying depreciation factors based on assumed average asset life. The world consists of OECD countries and a large list of developing non-communist countries.

the world distribution of capital allocated to the production of those commodities has been even more dramatic since the industrial distribution of investment outside the U.S. contrasts greatly with the distribution within the U.S. This accumulation of productive capacity around the world has been accompanied by a boom in world trade of unprecedented magnitude and a rapid leveling of wages of workers in the industrialized countries.* Although this process has largely reached its equilibrium among the developed economies, there remain vast differences in capital per man between the developed and underdeveloped world. The scene that has been played out by the industrialized countries may soon be replayed on a grander scale.

The Heckscher-Ohlin-Samuelson model with equal numbers of factors and goods is incapable of explaining these events. One of its implications is that factor prices are equalized around the world. Although the international economy is involved in a long term process of factor price equalization, factor prices across industrialized countries have been and remain today quite disparate. In 1967 average U.S. wages in manufacturing were 1.8 times the average manufacturing wage in OECD countries. Ten years later average U.S. wages were still 1.3 times as large as those in the OECD. Economic evidence supports a rejection of a short-run Heckscher-Ohlin model. Kotlikoff and Leamer (1981) find that national wages are systematically related to national endowments of productive factors.

The simple Heckscher-Ohlin model may be altered in many ways to eliminate the factor-price equalization theorem. This paper provides a theoretical

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*Branson (1980) describes the changes in trade and international investment in the post-war period.

structure which seem capable of explaining the events of the last three decades. The theoretical model takes factor-price equalization to be a feature of the steady-state equilibrium, but allows for costs which delay adjustment to this equilibrium. Costs could be incurred by either capital or labor. Here, as in Mussa (1978) and Mayer (1974), we allow labor to be costlessly mobile within each country, while capital is mobile, but subject to increasing costs. Summers (1980) provides econometric evidence supporting a putty-clay model of capital formation that involves significant marginal costs of quickly adjusting the size of the capital stock devoted to the production of any particular commodity. In recent years models of economic growth incorporating costly capital adjustment have been developed by Summers (1980), Lipton and Sachs (1980), and Sachs (1982). Each of these analyses have related investment to Tobin's q, the ratio of a firm's market value to the replacement cost of its capital. Lipton and Sachs (1980) and Sachs (1982) have analyzed the dynamics of international growth with costly adjustment under the assumption of complete specialization in production. This paper extends this literature by considering the case of international growth with incomplete specialization and costly adjustment. The model generalizes the Heckscher-Ohlin theory of international trade and factor compensation; the model we present reduces to the Heckscher-Ohlin model with internationally mobile capital under the assumption of zero adjustment costs. With positive adjustment costs, the model predicts Heckscher-Ohlin relationships, including factor price equalization, in the long-run, but not during the economy's transition path to its ultimate steady-state. An interesting feature of the model is that it provides a determinate solution to the long-run international allocation of the world's capital stock. This is true despite the fact that international capital mobility is permitted and despite the fact that the Rybchinski-theorem holds in the long-run.

The dynamic model that we construct is to be simulated for hypothetical technological and preference parameters under the assumption of both rational and myopic expectations. The simulations presented here assume myopic expectations. A computer program simulating the rational expectations transition path of dynamic international economies is currently being tested. The method of simulation under rational expectations is that of Lipton, Poterba, Sachs and Summers (1980). The simulations provide considerable insight concerning the time required for long-run factor price equalization and the relationship between domestic and foreign wages during the economic transition.

The second part of this paper tests the structural relationships posited by the model using industry specific investment, employment and wage data from the United Nation's Yearbook of International Statistics. Of particular interest is the extent to which the short-run industrial allocation of each nation's capital stock influences the short-run industrial allocation of each nation's labor force. In addition we examine the degree to which international investment responds to international differences in investment profitability and the consequences of such international, industry specific investment for employment in the corresponding domestic industries.

The paper proceeds as follows. The first section provides a statistical overview of the course of post-war international investment and factor price equalization. In Section 2 the 2-good 2-factor Heckscher-ohlin model is generalized to incorporate capital stock adjustment costs and economic growth. This section describes the long-run steady-state properties of the model as well as the economics of transitional growth. Section three tests the theory with the limited international data that is available. Section four summarizes and concludes the paper.

I. An Overview of International Investment and Factor Price Equalization

This section presents various types of evidence describing both the rapid post-war accumulation of capital in developed foreign countries and the course of international wage equalization. The changes in relative international capital endowments are substantial and appear to be having a profound influence on wages in the United States.

Table 1 indicates how the international distribution of the world's capital stock has changed in the past several decades. These capital stock numbers are generated using the perpetual inventory method assuming 20 year asset lives. The values of the U.S. share of world capital for the years 1958 and 1966 are most likely biased downward because of an underestimate of U.S. benchmark capital stock in 1948. (See Leamer (1980)). In the 1950's over half of the world's capital stock was located in the U.S. Today the figure is roughly 30 percent. The increase in the share of world capital located in Japan and Germany is almost large enough to account for the loss in the U.S. share. Japan now holds over 15 percent of the world's structures and equipment; 20 years ago less than 5 percent of the world's capital was located in Japan. Germany's share of world capital has almost doubled in the post-war period. The fraction of total world capital placed in Korea remained roughly constant for much of the last two decades. In recent years, however, Korea's share has also increased markedly.

Figure I details changes in international shares of world gross fixed capital formation. The information conveyed in this diagram reinforces the findings of Table I, yet does not incorporate a number of technical assumptions required to estimate actual capital stock numbers. The figure

Table I

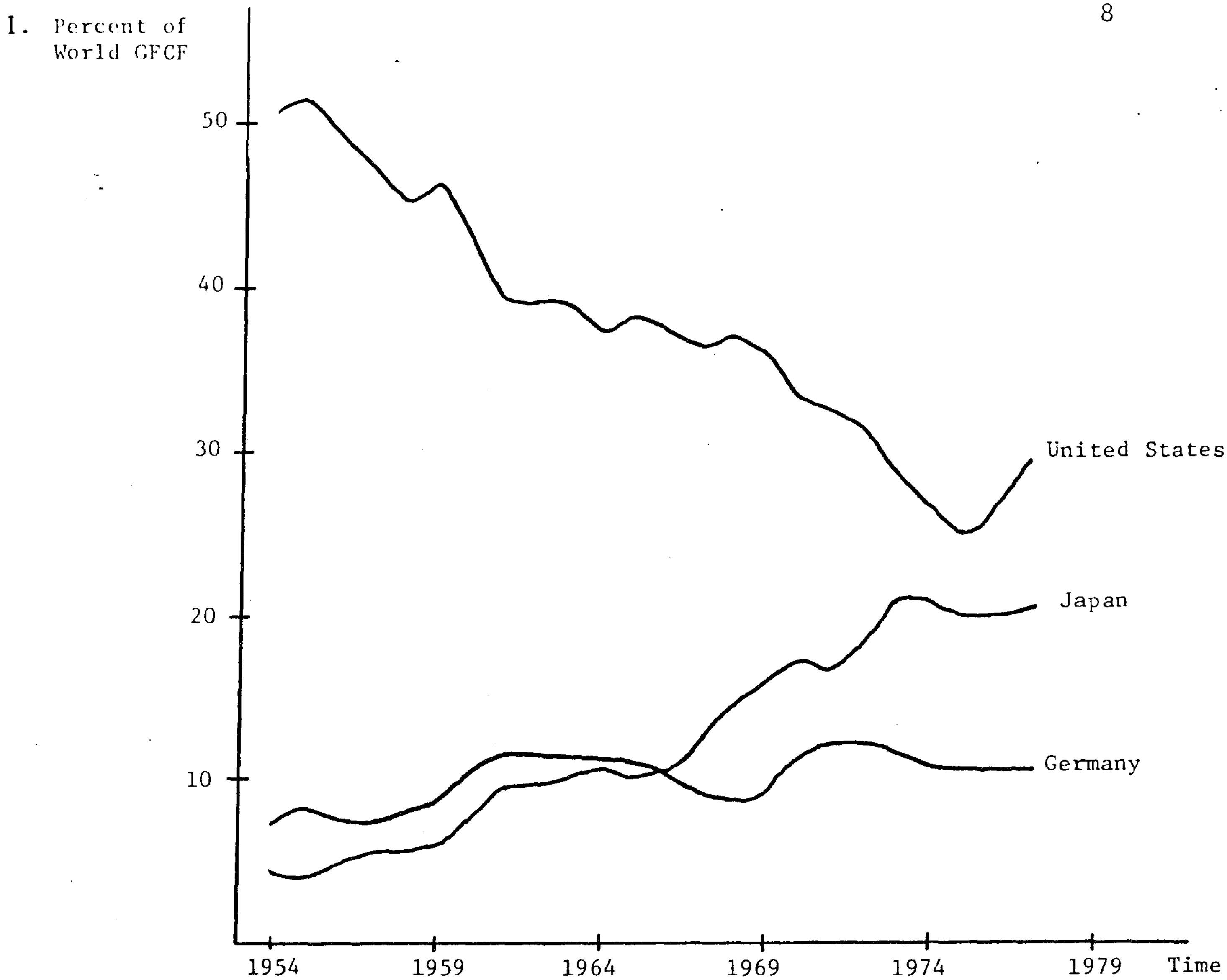
Changes in Geographical

Distribution of World Capital Stock*

Share of World Capital by Country

	1958	1966	1972	1975
U.S.	.5298	.3986	.3565	.3206
Japan	.0392	.0792	.1127	.1523
Germany	.0592	.0893	.1068	.1108
Korea	.0028	.0015	.0025	.0037

*Source: Statistical Appendix to Leamer (1980): "An Empirical Study of Changing Comparative Advantage," prepared by Harry P. Bowen.



SHARE OF WORLD GROSS FIXED CAPITAL FORMATION
FOR GERMANY, JAPAN, AND UNITED STATES
1954-1977

1) Germany changed national accounts system used to compute GFCF in 1960.
   Japan changed national accounts system used to compute GFCF in 1965.

2) List of countries comprising "World": Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

indicates that the U.S. share of gross capital formation exceeded 50 percent in the early 1950s; by the mid-1970s the U.S. share was approximately 30 percent. To compare foreign countries investment flows with those of the U.S. each foreign country investment series was converted into U.S. dollars using annual exchange rates. This procedure may overstate the recent reduction in the U.S. share of total world investment because of the significant depreciation of the U.S. dollar in the 1970s. A measure of capital accumulation that avoids this exchange rate issue is given in Table II.

Table II details the substantial difference in country specific investment rates that have generated the Table 1 changes in the distribution of world capital. The Japanese investment rate is the most striking. For many of the past twenty years the Japanese investment rate has been more than double that of the U.S. German investment rates, while much lower than those of the Japanese, have still exceeded U.S. rates by 25 to 50 percent. Indeed U.S. investment rates have been and are currently among the lowest of developed countries. Korea's investment rate shot up in the 1970's and now exceeds the U.S. rate by about 40 percent.

These large differences in domestic investment rates have for the most part been associated with large differences in domestic savings rates. Neither the high Japanese nor German investment rates reflect the import of foreign capital. On the contrary, as Table III reports, both Japan and Germany have experiences trade surpluses in the past two decades. In 1977 for example, Germany savings exceeded German investment by 11.43 percent. The Japanese have run much smaller surpluses as a fraction of their investment. In selected years the U.S. and the U.K. have been heavy importers of foreign capital. In 1977 almost 10

Table II

Gross Domestic Fixed Capital Formation

as a Fraction of Gross Domestic Product*

Countries	1960	1965	1970	1975	1977
United States	.177	.189	.174	.164	.175
Japan	.361	.305	.350	.322	.313
Germany	.243	.261	.264	.208	.209
Korea	.108	.149	.141	.252	.251
United Kingdom	.164	.182	.184	.201	.180
France	.202	.242	.254	.233	.226
Italy	.223	.190	.212	.206	.200
Canada	.217	.234	.209	.238	.226

*Source: International Financial Statistics, selected monthly reports, 1965-1979.

Table III

Fraction of Gross Fixed Capital Formation

Financed from Abroad*

Country	1960	1965	1970	1975	1977
United States	-.0261	-.0273	.0044	-.0486	.0999
Japan	-.0128	-.0375	-.0301	.0020	-.0528
Germany	-.1075	-.0025	-.0823	-.1389	-.1143
Korea	.8602	.4944	.4014	.3705	.0029
United Kingdom	.0955	.0446	-.0392	.1004	-.0045
France	-.0885	-.0355	-.0115	-.0319	.0230
Italy	.0882	-.0487	.0361	.0639	.0332
Canada	.0554	.0106	-.1299	.0617	.0014

*Trade deficit as a fraction of domestic investment.

percent of U.S. domestic investment resulted from foreign investment in the U.S. In the past two decades the U.K., Italy, Canada, and Korea have tended to import capital for purposes of domestic investment. Korea has been a particularly impressive importer of foreign capital. In certain years foreigners have invested more in Korea than have domestic residents.

The numbers in Table III suggest that the post-war placement of capital would not have been markedly different had net international capital flows always been zero. On the other hand, rates of net foreign investment have been high in certain years for certain countries, and this suggests that at least small variations in domestic savings rates would have left domestic investment rates unaltered.

The substantial international differences in savings rates are primarily the result of international differences in private household consumption behavior. Table IV reports the ratio of private household consumption to gross domestic product less government consumption. In 1977 private U.S. citizens consumed 77 cents of every dollar of national output left over after government consumption. In contrast Japanese citizens spent only 64 cents of every dollar of output not consumed by the Japanese government. Converted into savings rates, the 1978 Japanese savings rate out of output left over after government consumption was over 50 percent greater than that of the U.S.

The composition of domestic investment with respect to residential versus non-residential capital formation has been roughly similar in the U.S., Japan, Germany, and Korea. Table V indicates that the Japanese have allocated a somewhat higher fraction of their domestic investment to business plant and equipment than has the U.S.; the U.S. non-residential investment share is slightly higher than the German.

Table IV

Private Consumption Rates

by Country

Years	U. S.	Korea	Germany	Japan
1960	.81	.99	.66	.61
1965	.80	.87	.66	.62
1970	.82	.82	.65	.55
1975	.79	.78	.71	.64
1976	.79	.74	.70	.64
1977	.79	.71	.70	.64
1978	.77	.70	.69	.64
1979	*	.69	.68	*

Source: IFS; private consumption rate defined as private consumption/gross domestic product - government consumption (government consumption does not include government investments)

*Data not available

Table V

Share of Total Domestic Investment
Allocated to Non-Residential
Capital Formation*

	1960	1965	1970	1975	1977
United States	.728	.770	.792	.800	.724
Japan	.858	.811	.804	.765	.755
Germany	.706	.712	.742	.724	.717
Korea	.800	.886	.863	.825	.836

*Source: U.N. Yearbook of National Account Statistics, 1978.

While the type of investment undertaken in recent years has been similar in these countries, the industrial allocation of investment has differed substantially. Table VI compares Japanese, German and Korean 1967 to 1977 cumulative investment shares by industry with those of the U.S. Over the period 1967 to 1977 the Japanese invested disproportionately more in iron and steel, non-ferrous metals, pottery and glass, transport equipment, and tobacco than did the U.S. The Germans have invested relatively heavily in metals as well, but also in machinery, beverages, leather products and footwear. Korean investment is highly concentrated in textiles, leather products, wearing apparel, tobacco, rubber, iron and steel and non-ferrous metals. In contrast the U.S. has concentrated its investment in recent years relatively more in food products, wearing apparel, furniture, paper, printing, chemicals, petroleum, metal products, and professional goods and other industries.

While the numbers in Table VI indicate that foreign patterns of investment have been quite different from that in the U.S. in recent years, they do not indicate how investment patterns within the United States have changed over time. Table VII describes changes in the U.S. industrial composition of investment over the period 1967-1977. As the model to be presented below suggests, changes in the allocation of domestic investment provide excellent early predictors of changes in the structure of comparative advantage. Consider the metal industry as an example. Despite the fact that the U.S. devoted relatively more of its total investment to the metal products industry from 1967-1977 than did Japan, Germany, and Korea, the share of U.S. investment allocated to metal products declined continuously from 1967 through 1977. The 1967 share was 5.6 percent; in 1977 the share was 4.7 percent, 16 percent lower than in 1967. Textiles, leather products, footwear, rubber products,

Table VI

Cumulative Investment Shares 1967-77

Relative to U.S. Shares*

Industry	Japan	Germany	Korea
Food products	.7	.8	.8
Beverages	.8	2.0	1.0
Tobacco	9.4	1.2	3.4
Textiles	1.0	.9	5.8
Wearing apparel	.6	.9	2.6
Leather and products	.6	1.8	5.9
Footwear	.3	1.7	2.0
Furniture	.6	.8	.8
Paper	.7	.4	.3
Printing and Publishing	.6	.5	.3
Chemicals	.8	1.0	.6
Petroleum	.8	.7	.8
Rubber products	.8	1.0	1.4
Plastics	.9	1.0	.6
Pottery, china, glass	1.1	1.2	1.8
Iron and Steel	2.3	1.3	1.5
Non-ferrous metals	1.2	.7	.4
Metal products	.8	.8	.4
Machinery	.8	1.3	.4
Electrical machinery	1.0	1.3	1.2
Transport equipment	1.2	1.3	.9
Professional goods	.4	.5	.3
Other industries	.7	.3	1.0

*Source: U.N. Industrial Statistics.

Table VII

Changes in Composition of U.S. Investment,

1967-1968 - 1976-1977

Industry	1967-1968*	1976-1977*	Percentage Change in Share
Food Products	.0649	.0698	7.55
Beverages	.0179	.0215	20.11
Tobacco	.0023	.0035	52.17
Textiles	.0374	.0294	-21.39
Wearing Apparel	.0084	.0075	-10.71
Leather Products	.0014	.0009	-35.71
Footwear	.0019	.0011	-42.10
Wood/Furniture Products	.0231	.0287	24.24
Paper Products	.0671	.0718	7.00
Printing and Publishing	.0370	.0324	-12.43
Indust/Other Chemicals	.1427	.1823	27.75
Petro Ref/Coal Products	.0494	.0572	15.79
Rubber Products	.0187	.0108	-42.24
Plastic Products	.0155	.0228	47.10
Pottery/Glass Products	.0374	.0374	0.00
Iron and Steel	.1057	.0725	-31.41
Non-Ferrous Metals	.0327	.0247	-24.46
Metal Products	.0567	.0482	-14.99
Machinery	.0892	.0916	2.69
Electrical Equipment	.0778	.0592	-23.91
Transport Equipment	.0818	.0957	16.99
Professional Goods	.0215	.0194	- 9.77
Other Industries	.0088	.0110	25.00

Source: U.N. Industrial Statistics

*Average value for two year period.

iron and steel, non-ferrous metals, metal products, and electrical equipment are all industries that have suffered major reductions in their share of new U.S. capital formation. In contrast plastic products, wood/furniture products, transport equipment, tobacco, and the chemical industry are industries that enjoyed sizable increases in their share of total U.S. investment. The long-run reallocation of industrial capital suggested by these numbers is quite likely to be associated with a similar long-run reallocation of U.S. labor across industries.

The Table VI differences in the allocation of national investment across industries imply differences in the allocation of any particular industry's investment across countries. Table VIII indicates the U.S. share of total world investment by industry for 1967 and 1977 as well as the percentage change in these shares. The most dramatic changes in the international distribution of industrial investment have occurred in the leather, footwear, rubber, iron and steel, non-ferrous metals, metal products and electrical equipment industries. In 1967 over a third of the leather products industry's investment took place in the U.S. Today's figure is roughly one-fifth. The U.S. share of footwear investment has halved over the period, while the share of investment in the metal industries has fallen by 25 percent. The Japanese and Germans increased their share of world steel investment from 33 percent to 42 percent.

In the textile industry the U.S. has maintained its investment share at about 30 percent, while the textile investment shares of other countries have changed considerably. In 1967 Korea accounted for less than 2 percent of world textile investment. The current figure is close to 13 percent. Much of this Korean textile investment is substituting for Japanese textile investment. The Japanese formerly accounted for 16 to 20 percent of world

Table VIII

U.S. Share of International Investment by Industry*

Industry		1967	1977	Percentage Change in Share
311	Food Products	.399	.338	-0.153
313	Beverages	.301	.306	0.017
314	Tobacco	.105	.115	0.095
321	Textiles	.310	.311	0.003
322	Wearing Apparel	.335	.355	0.060
323	Leather Products	.345	.222	-0.357
324	Footwear	.310	.182	-0.413
33A	Wood/Furniture Products	.354	.372	0.051
341	Paper and Products	.479	.405	-0.154
342	Printing and Publishing	.472	.425	-0.100
35A	Indust/Other Chemicals	.418	.399	-0.045
35B	Petroleum/Coal Ref. & Products	.350	.389	0.111
355	Rubber Products	.429	.345	-0.196
356	Plastic Products, N.E.C.	.485	.424	-0.126
36A	Pottery/Glass Products	.299	.299	0.000
371	Iron and Steel	.418	.243	-0.419
372	Non-ferrous Metals	.382	.303	-0.207
381	Metal Products	.473	.354	-0.252
382	Machinery, N.E.C.	.523	.426	-0.185
383	Electrical Equipment	.479	.290	-0.395
384	Transport Equipment	.376	.361	-0.040
385	Professional Goods	.679	.539	-0.206
390	Other Industries	.475	.443	-0.067

*Source: U.N. Industrial Statistics.

textile investment. They now account for 12 percent. Investment in the wearing apparel industry has, on the other hand, increased in both Japan and Korea. Their combined investment share in 1967 was 8 percent, in 1977 it was 16 percent.

Post-war international differences in investment behavior have led to remarkable changes in international capital labor ratios. As Table IX points out the U.S. ratio of capital to labor exceeded the Japanese ratio by almost 9 to one in 1958. By 1975 the U.S. capital-labor ratio was less than 30 percent greater than that of the Japanese. German growth in capital intensity has been equally impressive. The Table IX estimates obtained from Leamer's (1980) data suggest that the German capital labor ratios actually exceeded the U.S. ratio by the mid-1970's. Korea has also experienced a phenomenal increase in capital intensity, but the differential today between the U.S. and Korean ratios of capital to labor is greater than the 1958 differential between the U.S. and Japan. Clearly the international equalization of the ratio of capital to labor is an on-going process that will continue for years if we can extrapolate the trends of the past.

The narrowing of international differences in capital-labor ratios has been associated with a rapid process of international factor price equalization. Figure II presents the ratios of U.S., German, Japanese, and Korean wages in manufacturing industries to the employment weighted average manufacturing wage among the developed western economy's plus Japan. In the decade from 1967 to 1977 the U.S. relative wage advantage declined by 25 percent; in 1967 the average U.S. manufacturing wage

Table IX

Changes in International

Capital Labor Ratios*

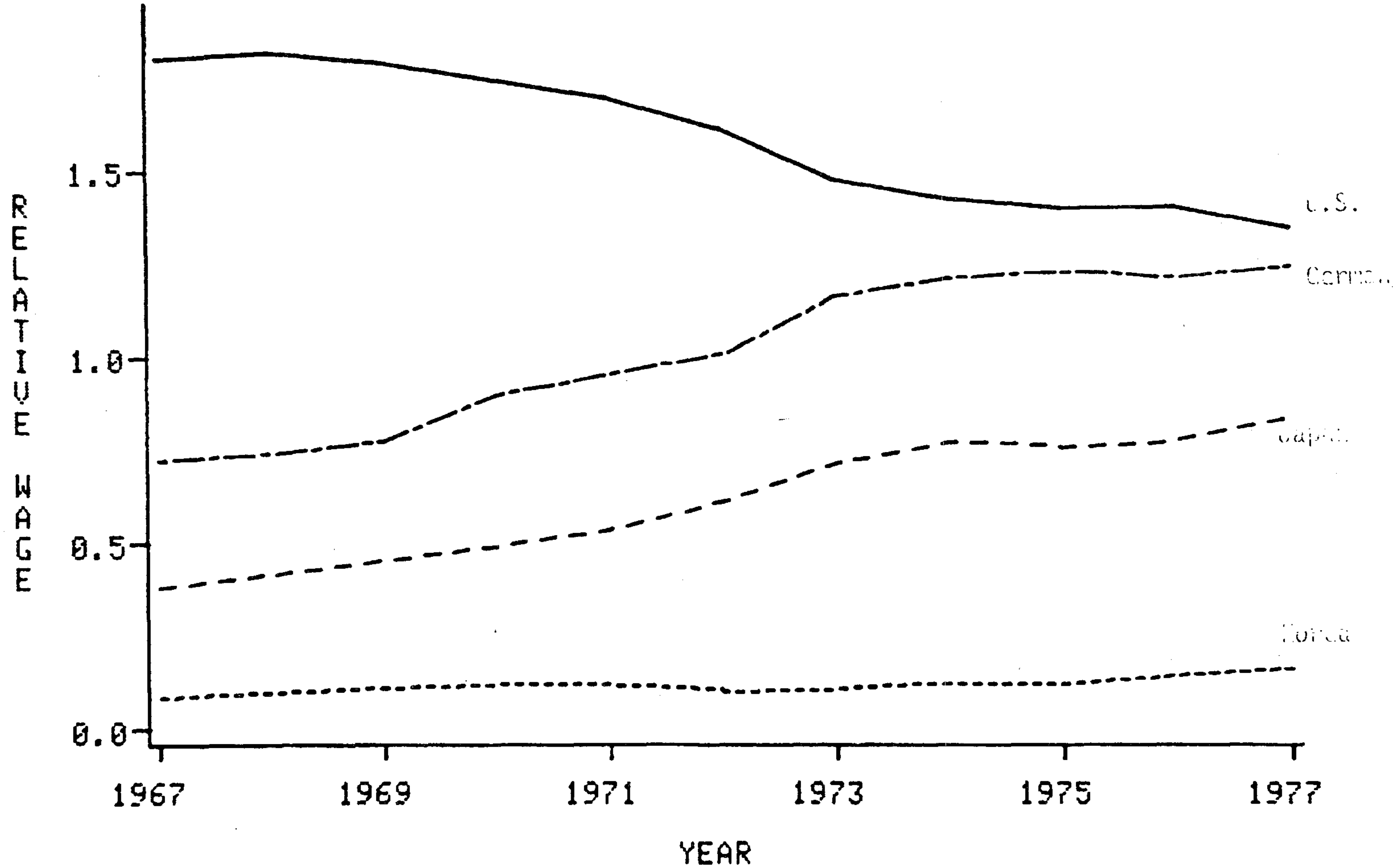
	1958	1966	1972	1975
United States	$ 9,554	$12,471	$14,453	$13,996
Japan	1,147	3,841	7,449	11,025
Germany	2,944	7,994	14,172	16,328
Korea	422	371	984	1,196

*Units are measured in 1960 dollars of capital per worker.

Calculations assume a 20-year life for capital depreciation.

Source: Statistical Appendix to "An Empirical Study of Changing Comparative Advantage," 1980.

II. **RELATIVE WAGES BY COUNTRY: 1967–1977**



UNITED STATES GERMANY JAPAN KOREA

was 1.8 times the international average. By 1977 the U.S. average annual manufacturing wage was only 1.35 times the international average considered here. As the data on growth in capital-labor ratios would suggest, Japanese and German relative wages have grown considerably. Not withstanding a doubling in the Japanese relative wages over the decade from .38 to .83, U.S. wages were still 60 percent greater than Japanese wages in 1977. Korea has also evidenced sustained growth in relative annual manufacturing wages. The Korean ratio was .087 in 1967; it was .175 in 1977.

Despite the rapid growth of capital intensity abroad, the equalization of international wages can not be fully explained by the equalization of international capital labor ratios. For example, our data suggests that the ratio of the Japanese capital labor ratio to that of the U.S. increased by almost 160 percent between 1967 and 1975. If one assumed that wages were determined by a linear homogeneous Cobb-Douglas production function with a capital coefficient of .3, this growth in relative capital labor ratios would imply a 48 percent increase in relative wages. However, from 1967 to 1975 Japanese relative wages themselves increased by almost 160 percent. A similar set of numbers holds true for Germany. Over the period 1967 through 1975 German capital intensity relative to that of the U.S. increased by 82 percent, but German relative wages increased by 120 percent over the time period.

In addition to foreign acquisition of capital, foreign acquisition of technology appears to be a major determinant of foreign wage growth. Table X presents growth rates of total factor productivity for the U.S., Germany, Japan, and Korea. The analysis is based on Leamer's (1980) data on national endowments as well as national outputs. To calculate these productivity indices we assumed that each country's gross domestic product could reasonably

Table X

Rates of Growth of

Total Factor Productivity*

	U.S.	Germany	Japan	Korea
1958-1960	7.02%	1.59%	17.57%	-2.70%
1960-1963	5.71%	3.96%	12.88%	11.89%
1963-1966	10.76%	6.48%	12.11%	14.90%
1966-1969	3.07%	11.39%	23.80%	-12.01%
1969-1972	2.46%	5.64%	8.76%	18.50%
1972-1975	-9.89%	-3.57%	20.18%	-7.72%
1958-1975 (Geometric Average)	1.03%	1.46%	4.67%	2.40%
1966-1975 (Geometric Average)	-.55%	1.41%	4.41%	2.08%

*Calculations based on GDP and input data reported in Leamer (1980). Output and capital input are measured in the home currency at 1966 prices. Country specific gross domestic product and gross domestic investment deflators are used in the calculations.

be described as arising from an aggregate Cobb-Douglas production function with a capital coefficient of .3. Our productivity measure is output per unit input where inputs (capital and labor) are geometrically weighted by their factor shares.

The computed productivity growth rates vary greatly from period to period. However, over the period 1958-1975 as well as the sub-period 1966-1975, Germany, Japanese, and Korea technological growth rates all exceeded those of the U.S. The Japanese growth rate in technology is striking; it averaged 4.67% over the 17 year period; this is 3.54 percentage points larger than the comparable U.S. growth rate. The close to 5 percent differential in technological growth rates between Japan and the U.S. during the period 1966 to 1975 can by itself account for a 56 percent increase in the Japanese-U.S. relative wage. Over the period 1958 to 1975 German growth rates were, on average, 40 percent greater than U.S. growth rates. In more recent years (1966-1975), the German-U.S. growth rate differential has averaged close to 2 percentage points and could explain a 19 percent increase in the relative German wage from 1966 to 1975.

For the most part the process of international wage equalization has occurred uniformly across all industries. With a few notable exceptions, U.S., German, and Japanese industrial wage structures have remained constant while absolute wage rates across all industries have grown closer to their foreign counterparts. Table XI examines changes in the industrial wage structure by country over the period 1967 to 1977 for the U.S., Japan, Germany, and Korea. With the exception of tobacco, iron and steel, wearing apparel, and footwear, industrial wages relative to an employment weighted average U.S. wage in the U.S. have changed by less than 10 percent. Only three industries in Japan, beverages

Table XI

Percentage Change in Relative Wages, 1967 to 1977*

Industry	U.S.	Japan	Germany	Korea
311 -- Food Products	0.01524	0.01349	-0.10551	0.21288
313 -- Beverages	0.09206	0.12385	-0.06323	0.37136
314 -- Tobacco	0.24106	0.00162	0.12199	-0.27829
321 -- Textiles	-0.01469	0.02239	-0.04946	-0.02795
322 -- Wearing Apparel	-0.12655	-0.07345	-0.06634	-0.04239
323 -- Leather Products	-0.08806	-0.11137	-0.17266	-0.35561
324 -- Footwear	-0.13480	-0.09117	-0.09196	-0.22176
33A -- Wood/Furniture Products	0.00024	0.00385	-0.03710	-0.12862
341 -- Paper and Products	0.04713	0.00998	-0.03502	-0.02859
342 -- Printing and Publishing	-0.05290	-0.03802	-0.00697	0.01153
35A -- Indust/Other Chemicals	-0.02304	0.03163	-0.02729	0.00961
35B -- Petro/Coal Ref & Products	0.09349	0.02174	0.02541	0.35522
355 -- Rubber Products	-0.01032	0.15029	-0.01641	-0.02555
356 -- Plastic Products, N.E.C.	-0.03058	0.04929	-0.02558	-0.20086
36A -- Pottery/Glass Products	0.02046	0.00841	-0.07278	0.10604
371 -- Iron and Steel	0.15477	-0.06283	-0.03987	0.37261
372 -- Non-ferrous Metals	0.05808	-0.08776	-0.00488	0.20494
381 -- Metal Products	-0.05094	-0.03954	-0.02205	0.04482
382 -- Machinery, N.E.C.	-0.01290	0.01387	0.01487	-0.01736
383 -- Electrical Machinery	-0.02966	-0.00018	0.03105	-0.00985
384 -- Transport Equipment	0.06582	-0.01215	0.03767	0.18098
385 -- Professional Goods	-0.03801	-0.07685	0.02260	-0.18123
390 -- Other Industries	-0.06022	0.01443	-0.01738	0.16022

*Source: U.N. Industrial Statistics.

leather products, and rubber, experienced relative wage changes of more than 10 percent. In Germany there were also only three industries, food products, tobacco, and leather products. For the U.S., Japan, and Germany these data support a view of internal labor mobility that precludes large inter-industry wage differentials. Surprisingly Korean data suggests quite sizable changes in relative industrial wages from 1967 to 1977. For example, relative wages in beverages rose by 37 percent, while relative wages in leather products declined by 35 percent.

To summarize this section, post-war data on investment, employment and wages indicate that the international economy is engaged in a process of transitional growth, with low wage developed and developing countries accumulating capital at a faster rate than the U.S. While most of this capital formation has been internally financed, international investment has been a significant factor in total investment in certain countries, in certain years. These high rates of foreign capital formation have raised the level of capital per workers and have an important if not decisive role in raising foreign wages relative to those in the U.S. The process of international wage equalization appears, for the most part, to have occurred uniformly across industries within the various countries, which suggests a freely mobile internal domestic labor market.

While international wage and capital intensity equalization has been remarkable in the past 30 years, a large gap in both wages and levels of capital per worker still remains.

The next section of this paper presents a model of international growth and wage equalization that captures many of the features of the international economy suggested by the data. The model assumes that domestic labor forces are costlessly mobile across domestic industries, but that financial capital is internationally mobile. The key element of the model, the assumption of costly adjustment of industrial capital stocks, leads to a series of predictions about the course of factor accumulation and factor price equalization that seems quite consistent with the stylized facts presented in this section.

II. A Generalized Heckscher-Ohlin Model of Economic Growth with Adjustment Costs

The key feature that differentiates our model from the standard Heckscher-Ohlin model of international trade is the assumption that firms incur costs to altering their level of capital in any finite period of time. The adjustment cost technology that is considered here expresses adjustment costs as an increasing function of the rate of investment (or disinvestment). Since the rate of investment depends on both the absolute level of the firm's (industry's) existing capital stock as well as the absolute level of new investment, a firm's investment decision today will affect its capital stock tomorrow and, therefore, its marginal adjustment costs tomorrow. This formulation of the problem links the production and investment decisions of the firm at one point in time to these decisions at other points in time as well. Rather than equate the marginal product of capital to a common rental rate as in the standard static trade model, firms in this environment alter their capital stocks over time to maximize the present value of profits where profits are net of adjustment costs. The relative immobility of physical capital does not preclude perfect national and international mobility of financial capital. The model assumes that economic agents are free to invest anywhere in the world and will continue to do so until annual net rates of return to investment in a particular industry are equated across all industries. This equality of net rates of return across industries substitutes for the standard static equilibrium condition that net rental rates on capital are equated. While the model departs from tradition in its treatment of capital, the standard trade theory assumption of costless domestic, interindustry labor mobility is maintained.

The implications of these assumptions for the short run behavior of the model are the following. First, wage rates will differ across countries in the short run despite the fact that countries have identical technologies, are incompletely specialized in production, and financial capital is internationally mobile. The world relative price of the two commodities is not sufficient here to determine wage rates. In the short run marginal revenue products of labor are equated across domestic industries, but marginal revenue products of capital are not. It is the satisfaction of both of these sets of conditions that leads to factor price equalization. However, as we demonstrate below, both conditions are satisfied in the long run when the economy has converged to a steady state characterized by incomplete specialization. Hence, if the economy converges to such a steady state, wage rates across different countries must converge as well.

A second feature of this model is that positive investment may take place even in those industries exhibiting low marginal revenue products of capital. The reason is simply that concentrating substantial levels of new investment in any given industry or set of industries within any year entails increasing adjustment costs; this will prove unprofitable relative to investing in low marginal revenue product, but low marginal adjustment cost industries.

Even if disinvestment occurs, the rate of disinvestment will be slow, again because of the assumption of increasing costs to that activity. A consequence of this is that specialization in production is an international economic phenomenon that will occur gradually if at all.

The Model

The demand side of the model is formulated as follows. Citizens in each country maximize an intertemporal utility function that for simplicity is taken to be of the form given in (1). Utility is a function of the consumption of goods 1 and 2. Good 1 is the numeraire good in the economy and is both a consumption good as well as the economy's single capital good.

$$(1) \qquad U = \int_0^{\infty} \log \left(u\, C_{1t}^{-\rho} + (1-u) C_{2t}^{-\rho}\right)^{-1/\rho} e^{(n-\alpha)t} dt$$

In (1) α is the rate of time preference, n is the economy's population growth rate, u is a consumption share preference parameter, and ρ determines both the elasticity of substitution between consumption of the two different goods at a point in time and consumption of the same good at different points in time. All variables in the model are expressed per-capita. A similar function holds for the foreign country with subscripts F on all the variables.

The home country's budget constraint is given by:

$$(2) \qquad \int_0^{\infty} \{C_{it}\, e^{\left(nt - \int_{s=0}^{t} r_s ds\right)} + P_t C_{2t} e^{\left(nt - \int_{s=0}^{t} r_s ds\right)}\} dt$$

$$= g_{10}k_{10} + g_{20}k_{20} + g^{*}_{1F0}z_0 + H_0 \equiv A_0$$

Equation (2) states that the present value of domestic expenditures on the two commodities (P_t is the relative price of good 2) equals the present value of total domestic assets, A_0. These assets include human capital H_0, as well as claims to physical assets K_{10}, K_{20}, and z_0. The domestic capital stocks in industries 1 and 2 at time zero are K_{10} and K_{20} respectively. The term z_0 corresponds to domestic ownership of industry 1's capital in the foreign country. Since there is no uncertainty in this model and returns on investment are equated world-wide, domestic residents are indifferent between holding foreign capital in industry 1 or in industry 2. Hence, there is no behavioral consequence for the model in assuming that domestic residents concentrate their foreign portfolio in industry 1.

Maximization of (1) subject to (2) yields the demand expressions:

$$(3)\quad C_{1t} = \left(\frac{1}{1 + \left(\frac{1-\mu}{\mu}\right)P_t^{-\rho}}\right)(\alpha-n)A_0 e^{\int_0^t r_s ds-\alpha t}$$

$$(4)\quad C_{2t} = \frac{1}{P_t\left(\frac{\mu}{1-\mu}P_t^{\rho} + 1\right)}(\alpha-n)A_0 e^{\int_0^t r_s ds - \alpha t}$$

In the steady state per-capital consumption of each of the two goods stays constant; hence, $r = \alpha$ in the steady-state. A similar set of equations hold for the foreign country.

The supply relationships of this model are derived by noting that firms maximize the present value of profits. In industry 1, for example, profits are given by:

$$(5)\quad \pi = \int_0^\infty (F(K_{it},L_{it}) - w_t L_{1t} - I_{1t}) e^{-\int_0^t r_s ds}\, dt$$

In (5) I_{1t} is industry 1's total investment expenditure in year t inclusive of adjustment costs. We let J_{it} stand for the actual installation of new units of capital and parameterize the investment relationship in (6):

$$(6) \quad I_{it} = J_{1t} + \frac{\gamma}{2}\left(\frac{J_{1t}}{K_{1t}}\right)J_{1t}$$

The second term on the right hand side of (6) reflects the costs of varying the level of the industry's capital stock and exhibits increasing marginal costs to such activity. The industry increases its net capital stock according to formula (7) where d is the depreciation rate.

$$(7) \quad \dot{K}_{1t} = J_t - (n+d)K_{1t}$$

Maximization of (5) subject to (6) and (7) leads to the following first order conditions:

$$(8) \quad \frac{J_{1t}}{K_{1t}} = \left(\frac{q_{1t} - 1}{\gamma}\right)$$

$$(9) \quad X_{L1t} = w_t$$

$$(10) \quad X_{k1t} = -(n+d-r)q_{1t} - \frac{d}{2}\left(\frac{J_{1t}}{K_{1t}}\right)^2 + \dot{q}1t$$

For industry 2 profit maximization requires:

$$(11) \quad \frac{J_{2t}}{K_{2t}} = \frac{q_{2t} - 1}{\gamma}$$

$$(12) \quad P_tX_{L2t} = w_t$$

$$(13) \quad P_tX_{k2t} = -(n+d-r)q_{2t} - \frac{d}{2}\left(\frac{J_{2t}}{K_{2t}}\right)^2 + \dot{q}_{2t}$$

In the steady state $\dot{q}_{1t} = \dot{q}_{2t} = 0$, and $\frac{J_{1t}}{K_{1t}} = \frac{J_{2t}}{K_{2t}} = n + d$. The steady state values for the q's are therefore, $1 + \gamma(n+d)$.

Equations corresponding to the three above hold for the production decisions of foreign firms. Under the assumption of linear homogeneous production technologies, the marginal product terms, e.g., F_{L1} and F_{K1}, can be written as functions of their respective capital labor ratios, e.g., $\frac{K_{1t}}{L_{1t}}$.

The equilibrium conditions for this economy, (14), (15), and (16), reflect, respectively, the requirements of full employment, international financial arbitrage, and market clearance.

$$L_1 + L_2 = 1 \tag{14}$$

$$L_{1F} + L_{2F} = 1$$

For simplicity both countries are taken to be of equal size in terms of their labor forces which are normalized to unity.

$$r = \frac{DIV_{1t}}{q_{1t}} - \frac{\dot{q}_{1t}}{q_{1t}} \tag{15}$$

$$r = \frac{DIV_{2t}}{q_{2t}} - \frac{\dot{q}_{2t}}{q_{2t}}$$

$$r = \frac{DIV_{1Ft}}{q_{1Ft}} - \frac{\dot{q}_{1Ft}}{q_{1Ft}}$$

$$r = \frac{DIV_{2Ft}}{q_{2Ft}} - \frac{\dot{q}_{2Ft}}{q_{2Ft}}$$

The DIV terms in (15) correspond to the dividend paid out by the firm and are implicitly defined in equations (10) and (13) for the home country.

(16) $$X1 + X1F = C1 + C1F + I1 + I1F + I2 + I2F$$

Equation (16) states that the total world output of good 1 must satisfy the total world consumption demand for good 1 plus the total world investment demand for good 1.

Finally we note that z, the stock of wealth that domestic citizens own abroad evolves as:

(17) $$q_{1F}\dot{z} = (r-n)zq_{1F} + (X1 + PX2 - C1 - PC2 - I1 - I2)$$

Steady State Properties of the Model

In the steady state the model reduces to the following set of equations for the home economy:

(18) $$r = \alpha$$

(19) $$\alpha = \frac{X_{K1}(\frac{K_1}{L_1}) + \frac{d}{2}(n+d)^2}{1 + (n+d)} + (n+d)$$

(20) $$w = X_{L1}(\frac{K_1}{L_1})$$

(21) $$w = PX_{L2}(\frac{K_2}{L_2})$$

(22) $$\alpha = \frac{PX_{K2}(\frac{K_2}{L_2}) + \frac{d}{2}(n+d)^2}{1 + (n+d)} + (n+d)$$

Equations (18) through (22) suffice to determine the steady state equilibrium values of r, $\frac{K_1}{L_1}$, w, $\frac{K_2}{L_2}$ and P. The foreign analogues to (19) determines $\frac{K_{1F}}{L_{1F}}$, which, in turn, determines w_F as in (20). Given w_F, the foreign equivalents to equation (21) and (22) give two equations in P and $\frac{K_{2F}}{L_{2F}}$. But since P is determined in (18) through (22), the model is seemingly overdetermined. However, if the foreign and domestic technologies are identical, the pre-determined value of P is the solution value for these foreign equations as well. If technologies are identical, then $w = w_F$ in the steady state. If technologies are not identical, specialization must occur in the long run. This is simply a restatement of the standard analysis of the static trade model with internationally mobile capital.

Another feature of equations (18) through (22) and their foreign counterparts in that there is nothing in these equations that pins down the absolute level of the capital stock in each country in each industry. This is the standard Rybczynski result, but there is a twist. Given a steady state distribution of the world's capital stock, steady state equilibrium requires that the distribution remain constant. Any departure from the steady state distribution would require additional non-remunerative adjustment costs and, hence, would not be incurred.

While the final steady state international distribution of the world's capital stock cannot be determined from the steady state equation above, the steady state distribution is determined by the world economy's initial conditions. Consider some perturbation of the initial steady state level of capital in any of the four industries in the model. Profit maximization will involve choosing that transition path back to steady state equilibrium that, ceteris paribus, involves the smallest present value of adjustment costs. Since the adjustment costs depend on the actual capital in place, the placement of incremental capital will be determined by the initial placement of capital. Hence, the final steady state capital stock distribution will be a function of the initial capital stock distribution.

Simulations

The dynamic model presented above was simulated for a set of technological and preference parameter values under the assumption of myopic expectations. The authors are still developing procedures for conducting these simulations for the case of rational expectations. To implement the myopic expectations assumption, the equations presented above are rewritten with all price variables reflecting changes set equal to zero. Thus economic agents act as if they believe that current prices will remain at their current values forever. While a systematic comparison of rational expectations with myopic expectations remains to be done, there is good reason to believe that simulations based on myopic expectation will exhibit faster convergence to the new steady state than will similations based on rational expectations. The reason is simply that agents will not take sufficient account of future general equilibrium dampening effects on prices in making current investment and consumption decisions. For example, an increase today in the marginal revenue product of an industry will be taken to last forever, when in fact the increased industry investment that will occur today will reduce that commodity's relative price as well as marginal physical product in the future. Hence, there will be an overreaction to exogenous shocks in a myopic expectations model that will more quickly return the economy to long run equilibrium.

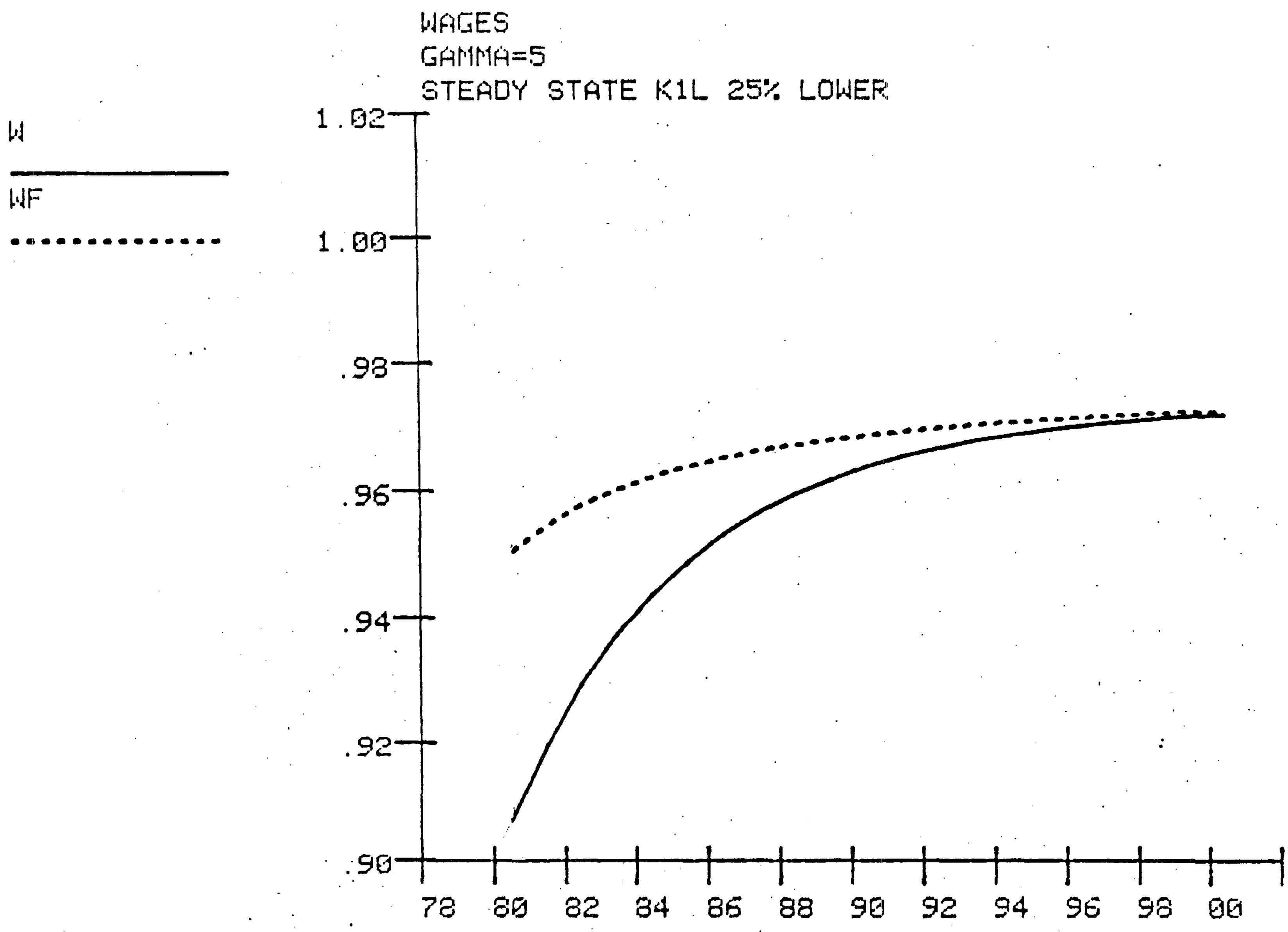
The simulation parameters are given the following initial values; the capital coefficient in the assumed Cobb-Douglas production functions in both industries equals .3, depreciation rates equal .03, the consumption preference share is .5, the time preference rate is equal to .1, the value of μ is .5, and the population growth rate is equal to zero. The adjustment cost coefficient, γ, is set to 5. This value implies that 7 percent of steady state investment corresponds to adjustment cost expenditure.

Initial steady state values of the model are calibrated by simulating the model until a steady state is reached starting with initial values of all capital stocks in both countries equal to 1.8. The initial value of z, domestic ownership of foreign assets, is set equal to zero.

The final steady state that was generated based on these country symmetric initial values was itself symmetrical across countries. The capital stock in industry 1 at home and abroad, K1 and K1F, obtained long run values of 1.586. The long run values for K2 and KLF were 1.414. In both countries 53 percent of the labor force is allocated to the production of commodity 1. That more resources are devoted in the long run to the production of commodity one is not surprising given that commodity one serves as both a consumption good and the world's single capital good. The steady state interest rate is .1, equal to the pure rate of time preference, α, and the steady state wage is .923. The fact that production functions in both industries are identical implies that the steady state relative price, P, equals unity.

The first experiment conducted involved a 25 percent reduction in the value of K1, the domestic country's capital in industry 1. Figures III and IV illustrate the transition path of wages and capital stocks back to the steady state. Table XII presents the values of various endogeneous variables for different years along the transition path. The year 80 is taken as the first year of the transition. As the figure and table indicate, domestic wages fall by seven percent in the first year after the capital stock reduction. Interestingly foreign wages are also reduced

Figure III


WAGES
GAMMA=5
STEADY STATE K1L 25% LOWER
W
WF
1.02
1.00
.98
.96
.94
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.90
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80
82
84
86
88
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92
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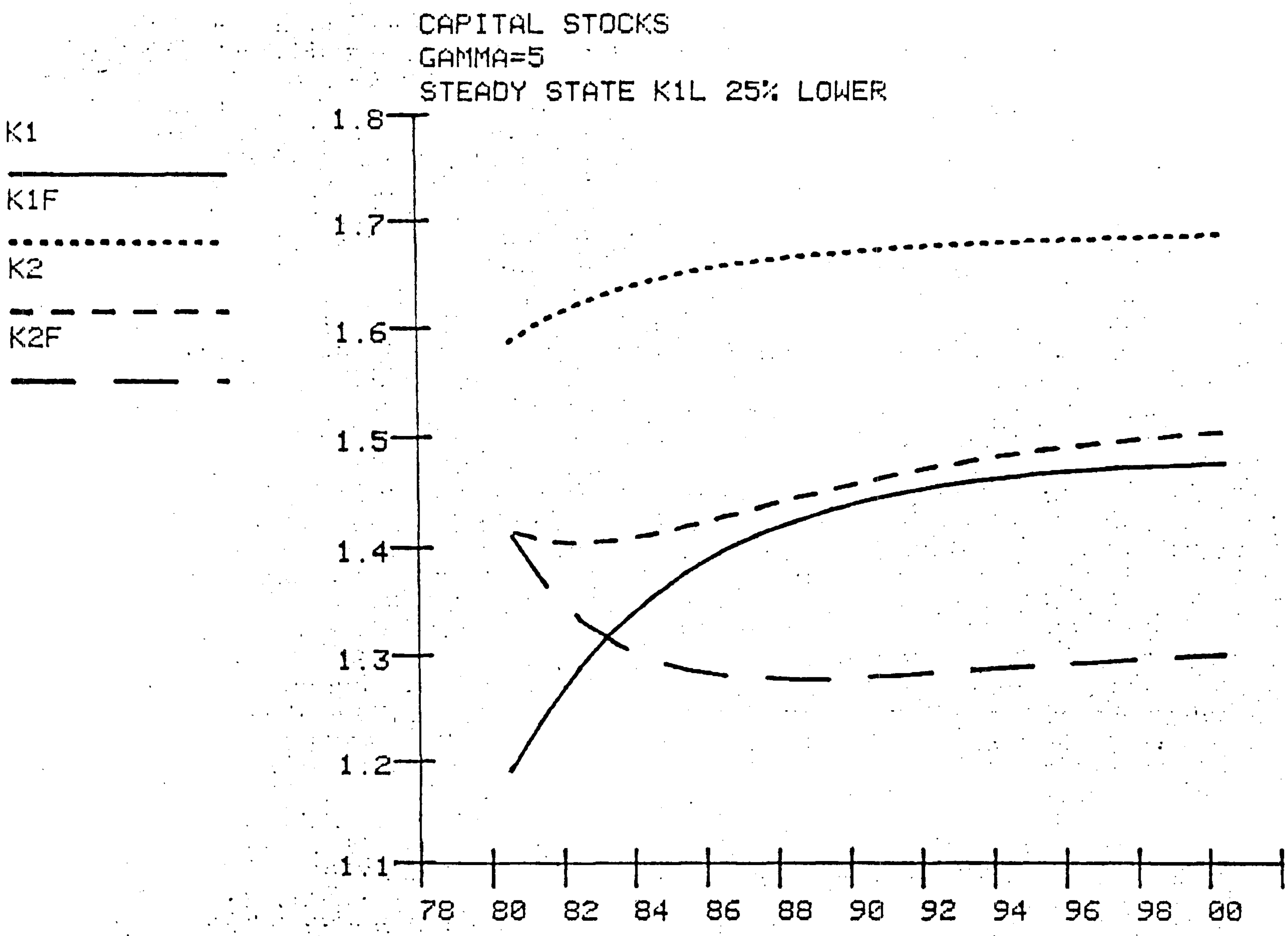
98
00

Figure IV


CAPITAL STOCKS
GAMMA=5
STEADY STATE K1L 25% LOWER
K1
K1F
K2
K2F
1.8
1.7
1.6
1.5
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1.3
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78
80
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00

Table XII

The Myopic Economic Transition Path

in Response to a 25%

Reduction in K_1

Variable	Year 80	82	85	90	95	150
K_1	1.189	1.289	1.378	1.443	1.466	1.482
K_2	1.414	1.402	1.419	1.460	1.488	1.518
K_{1F}	1.586	1.622	1.651	1.672	1.680	1.690
K_{2F}	1.414	1.332	1.286	1.280	1.290	1.310
L_1	0.502	0.501	0.500	0.497	0.496	0.494
L_2	0.498	0.499	0.500	0.503	0.504	0.506
L_{1F}	0.573	0.571	0.569	0.566	0.565	0.563
L_{2F}	0.427	0.429	0.431	0.434	0.435	0.437
w	0.907	0.929	0.949	0.964	0.969	0.973
w_F	0.950	0.958	0.964	0.969	0.971	0.973
q_1	1.356	1.265	1.194	1.148	1.134	1.125
q_{1F}	1.190	1.162	1.143	1.132	1.128	1.125
q_2	1.091	1.135	1.155	1.148	1.138	1.125
q_{2F}	0.952	1.041	1.105	1.132	1.133	1.125
I_1	0.100	0.077	0.059	0.046	0.042	0.039
I_{1F}	0.066	0.057	0.051	0.047	0.046	0.045
I_2	0.027	0.041	0.047	0.047	0.044	0.040
I_{2F}	-0.013	0.011	0.028	0.036	0.037	0.035
P	0.948	0.974	0.992	1.000	1.001	1.000
r	0.101	0.101	0.101	0.100	0.100	0.100

in the first year after the capital stock reduction, but only by two percent. Wages rebound quite promptly in this simulation. After four years half of the gap between the initial value of w, .907, and its final value of .973 has been closed.

As mentioned, the economy's history determines the final steady state distribution of the world's capital stock. In this case K1 is permanently reduced from its initial steady state magnitude of 1.586 to a new steady state value of 1.482. Final steady state K1F is 1.690. This long run relative capital stock distribution between the two countries is reversed in the case of capital in industry 2. The home country ends up with 15 percent more capital in industry 2 than the foreign country. There is an associated 6 percent long run reduction in domestic employment in industry 1 and a 6 percent increase in domestic employment in industry 2. These domestic changes, however, take place gradually. The first year there is only a 3 percent employment reallocation. The foreign employment effects are more pronounced. Employment in foreign industry 1 rises by over 8 percent in the first year to .573 and then gradually declines to .563. L2F falls immediately from .471 to .427 and then rises slowly to .437.

These long run changes make intuitive sense. The reduction in capital in domestic industry 1 lowers the world capital labor ratio. Demand for capital is stimulated both at home and abroad. The relative price of good 2 falls by 5 percent in the first year after the capital shock. This higher relative price of good 1 raises q_1 and q_{1F} and induces more investment in industry 1 both home and abroad. q_1 rises initially to 1.356, 20 percent above its long run value of 1.125. q_{1F} rises to 1.19. The reason for this differential is the higher initial foreign wages. These relatively higher foreign wages coupled with the low price of good 2 depress the foreign stock market price of industry 2, q_{2F}, by 15 percent. q_2, on the other hand, only falls by 3 percent, again primarily because of the lower domestic wages. These stock market revaluations lead to accelerated investment in the capital goods industry at home and abroad and to actual short run world wide disinvestment in industry 2. This disinvestment is more pronounced in the foreign country. Net capital formation is negative for 6 years following the shock in industry 2 abroad, it is negative for only one year for home industry 2. Figure IV indicates that capital stocks can overshoot their final steady state values. K2F provides an example of this; it reaches its minimum value about 8 years after the capital shock.

Domestic ownership of foreign assets, z, moves from an initial steady state value of zero to a final steady state value of -.20. This means that foreigners end up owning 6 percent of the domestic capital stock and are permanently better off than domestic residents.

To determine how the rate of wage convergence depends on the adjustment cost parameter, γ, a simulation identical to that just presented was performed for $\gamma = 8$; this constitutes a 60 percent increase in adjustment costs relative to the first simulation and implies that 11 percent of steady state investment is spent on capital installation costs. Despite the higher adjustment costs, international wage convergence still occurs quite rapidly. Half of the gap between initial domestic wages and long run wages is closed within 6 years. About 6 years is also required for K_1 to close half of the gap between its initial and terminal values. The general characteristics of the capital stocks transition paths are quite similar to those of the previous sample.

Figures V and VI depict the transition paths of domestic and foreign wages as well as capital stocks in response to a shock to the system consisting of a 25 percent reduction in domestic capital in both industries. As one might expect, initial domestic wages fall by more than in the previous case in which only K_1 is reduced. However, the marginal reduction in domestic wages is not very great. First year domestic wages fall by 7 percent when K_1 alone is reduced by 25 percent; they fall by 9 percent when both K_1 and K_2 are reduced by 25 percent. Since the reduction in K_2 eliminates part of the relative scarcity of commodity 1, the first year relative price falls by only 2 percent, rather than 5 percent. This appears to have an impact on long run K_{2F}. In contrast with our first simulation, long run K_{2F} is now greater than its initial value. Long run K_1 ends up slightly higher than its initial long run value as well.

Simulations were next performed based on the same initial set of parameter values with the exception of the capital coefficient in the production functions of industry 2 both at home and abroad. This coefficient was set equal to .4 rather than .3. Additional simulations were run with varying values of the consumption share μ, the time preference parameter γ, and the preference parameter ρ. The general pattern of transitional response to capital stock shocks in these exercises was quite similar to those described above. Capital stocks essentially reach long run equilibrium values within 20 years; wages are extremely close to their long run values after 25 years.

Figure V

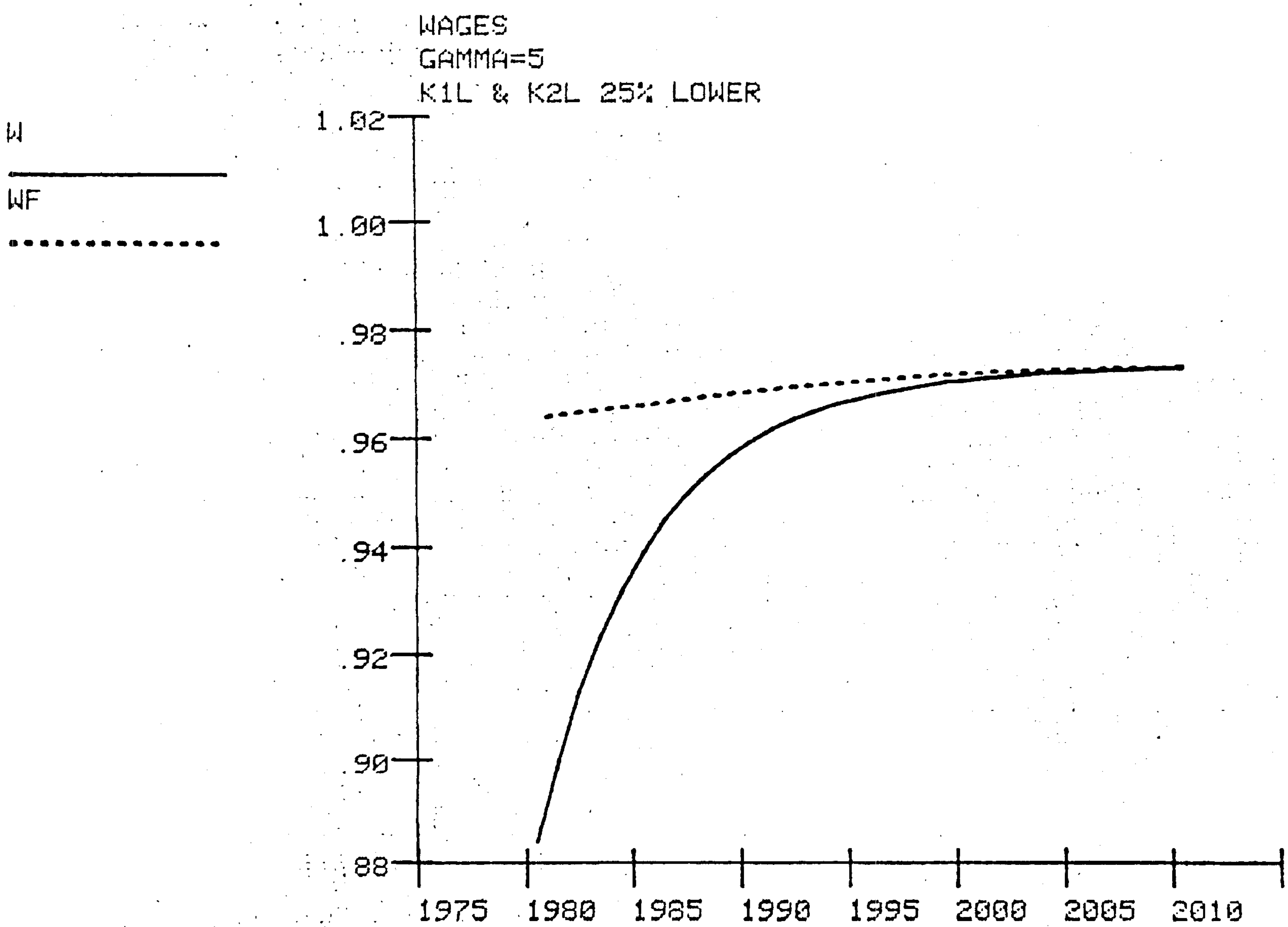
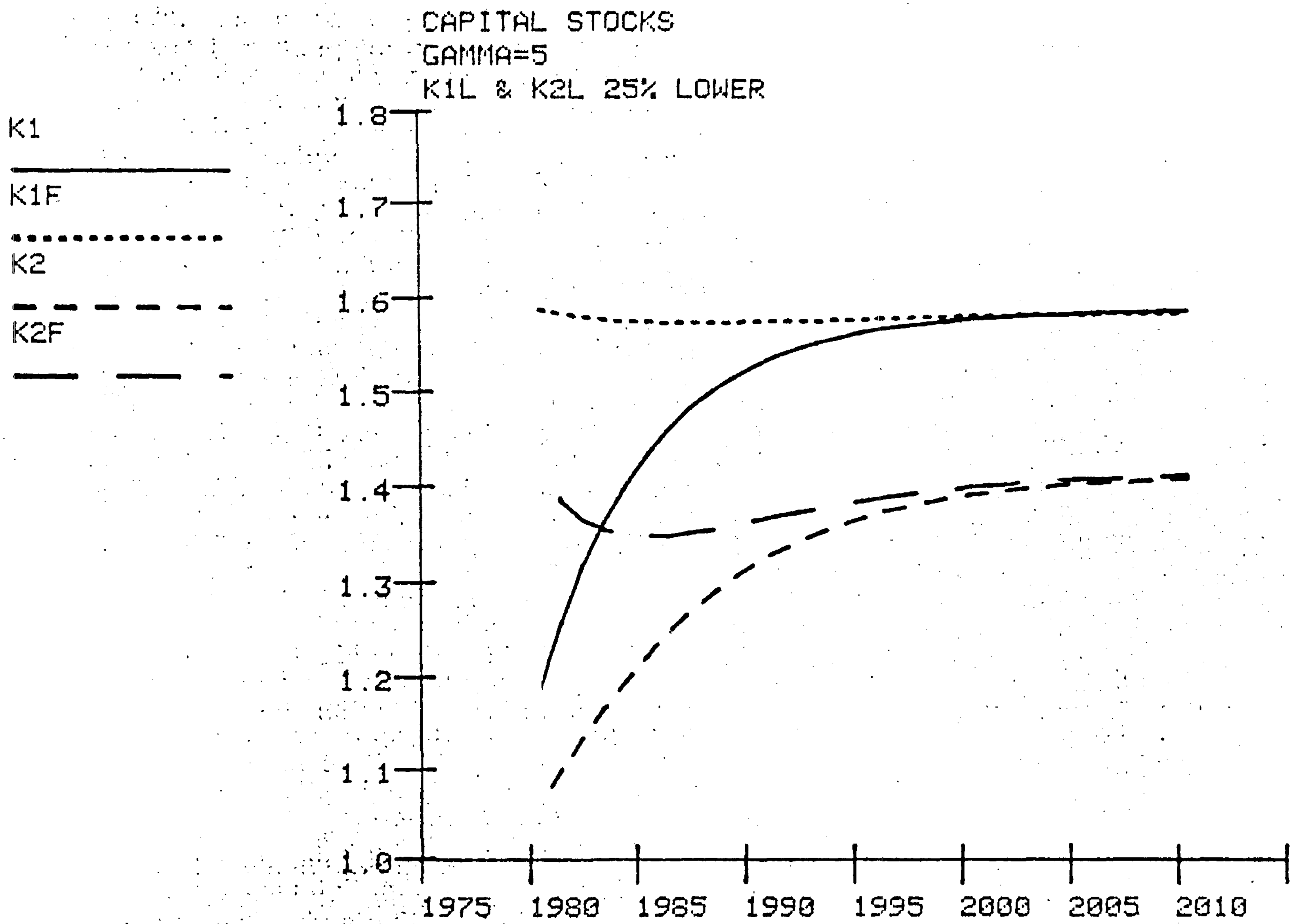

WAGES
GAMMA=5
K1L & K2L 25% LOWER
W
WF
1.02
1.00
.98
.96
.94
.92
.90
.88
1975
1980
1985
1990
1995
2000
2005
2010

Figure VI


CAPITAL STOCKS
GAMMA=5
K1L & K2L 25% LOWER
K1
K1F
K2
K2F
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
1975
1980
1985
1990
1995
2000
2005
2010

The final simulation conducted represents an attempt to roughly reenacted world conditions as of the early 1960's. The developed European countries and Japan are taken as the foreign country, while the U.S. is taken to be the home country. Leamer's (1980) data on national endowments indicates that in the early 1960's the U.S. labor force was half that of the European developed countries plus Japan, while it's capital stock was roughly equal in size. Foreign capital labor ratios were, therefore, about half of U.S. capital labor ratios. To incorporate these facts, the model was altered to give the foreign country twice the labor force of the home country. Next a simulation was performed taking the initial capital labor ratios in the foreign country to be half those of the home country.

In contrast with their terminal steady state values of .973, the foreign country's wage in the first year of the transition is .767 while the home country's wage is .945. The initial wage differential between the two countries is almost 20 percent; after 5 years the wage gap has closed to 6 percent. While the home and foreign wage differential is sizable, it falls far short of the actual wage differential observed in the early 1960's between the U.S. and her principle trading partners (see Figure II). On the other hand the model predicts a fairly rapid convergence of international wages, which is a striking feature of the postwar data (see Figure II).

It is interesting to note that increasing the size of the foreign country in terms of its labor force makes the home country wages more sensitive to foreign developments. If the foreign country were the same size as the home country initial home country wages would have been .773 rather than .767 and foreign wages would have been .952 rather than .945.

Throughout these simulations the world ratio of capital to labor has affected a country's wages even given its own capital-labor ratio. In this example the larger is the foreign country, the larger is the reduction in the world capital labor ratio associated with a given percentage reduction in the foreign country's capital-labor ratio.

These simulation exercises have important implications for wage and measured productivity growth. One conventional measure of productivity growth is output per man hour. In the model presented here output per man hour can be written as a function of the economy's wage; hence, productivity growth and wage growth are equivalent here. The exercises indicate that during a period of international economic transition, wages in countries with low levels of capital per worker will grow at much faster rates than those with high capital labor ratios. In the simulation just mentioned, for example, foreign wages grow by 5 percent in the first year of the transition while domestic wages grow by less than .5 percent.

The general picture that emerges from these simulations is one of fairly rapid international wage equalization as well as capital stock restoration; these processes are consistent with the international data described in section I. The simulations suggest that the inter-industry reallocation of the labor force associated with international capital stock shocks of the kind associated with World War II can be substantial in magnitude and persist indefinitely.

Future research will explore the extent to which the rate of international wage convergence depends on the expectations mechanism assumed. It may well be the case that international economic convergence is a much slower process for rational expectations economies than for myopic expectations economies.

III. Empirical Analysis of Investment, Employment and Wages

This section uses United Nations Industrial Statistics to test a number of theoretical relationships posited in the model of section II. The data covers the years 1967 to 1977 and details levels of employment, investment, value added, and wages for the set of manufacturing industries included in the tables of section I. The country coverage is somewhat limited due to non-reporting of data. While certain countries are omitted in certain regressions because of lack of data, our basic set of countries include the western developed economies of Europe and North America plus Japan, Korea, Colombia, Ecuador, Panama, Australia, New Zealand, the Phillipines, Turkey and Greece.

Determinants of International Investment

The putty-clay growth model of section II suggests that the rate of investment may be expressed as a linear function of Tobin's q, the ratio of the industry's market value to its replacement cost:

$$\frac{I_t}{K_t} = \alpha + \beta q_t \tag{1}$$

In the absence of stock market data detailing the industry's market price we express q_t as the discounted value of total current profits divided by the current capital stock:

$$q_t = \frac{\pi_t}{r \cdot K_t} \tag{2}$$

This formulation of q_t is appropriate for the case of myopic expectations, but should serve as a reasonable proxy for the case of rational expectations as well.

The lack of information concerning the level of K_t precludes estimating the investment function in the form specified in equation (2). However, by noting that $K_t = DK_{t-1} + I_{t-1}$, where D equals one minus the depreciation rate, equations (1) and (2) may be tranformed to yield:

$$(3) \qquad I_t = (\alpha + D)\ I_{t-1} + \frac{B\pi_t}{r} - \frac{BD\pi_{t-1}}{r}$$

Table XIII reports cross-country time series estimation of equation (3) for our 23 industries. Profits, π_t, is computed as an industry's value added less its total employee compensation. The investment and profit series were first converted to dollars using annual exchange rates and then deflated by the U.S. non-residential fixed investment deflator. This procedure insures that the replacement cost of capital is always unity. The real interest rate, r, is assumed fixed over the 10 year time period.

The regression results of Table XIII confirm the theoretical relationship between investment rates and profit rates. 40 of the 46 profit coefficients exhibit the correct sign. 37 of these coefficients are significant at the 5 percent level. Only 2 of the 6 coefficients with incorrect signs are statistically significant.

The absolute value of the coefficient on current and lagged profits are quite close in magnitude as the specification would suggest. Investment in the pottery/glass products industry is most sensitive to profitability. For this industry, a dollar increase in current profits leads to a 23 cent increase in current investment. If we take V in equation (3) to be of the

Table XIII

Cross-Country Time Series

Investment Regression Coefficients*

Industry	Profit	Profit Lagged	Investment Lagged	R^2
Food Products	0.045 (4.262)	-0.042 (3.681)	0.940 (36.234)	.99
Beverages	0.090 (4.374)	-0.668 (3.253)	0.791 (14.426)	.96
Tobacco	-0.015 (2.635)	0.019 (3.008)	0.948 (29.316)	.92
Textiles	0.134 (11.970)	-0.153 (11.585)	1.016 (29.361)	.97
Wearing Apparel	0.029 (4.463)	-0.028 (3.608)	0.932 (20.347)	.96
Leather and Products	0.019 (1.538)	-0.006 (0.485)	0.769 (15.865)	.89
Footwear	0.093 (9.709)	-0.093 (9.275)	0.880 (21.114)	.94
Wood/Furn Products	0.096 (11.547)	-0.095 (8.485)	0.927 (21.179)	.96
Paper and Products	0.101 (9.101)	-0.052 (3.930)	0.740 (25.380)	.98
Printing and Publishing	0.116 (11.779)	-0.132 (10.784)	1.036 (40.535)	.99
Indust/Other Chemicals	0.080 (4.579)	-0.048 (2.355)	0.795 (22.184)	.98
Petro Ref/Coal Products	-0.020 (0.862)	0.039 (1.325)	0.928 (21.699)	.95
Rubber Products	0.117 (5.390)	-0.128 (4.732)	0.952 (21.349)	.93
Plastic Products	0.167 (19.672)	-0.179 (16.216)	0.943 (25.588)	.98
Pottery/Glass Products	0.235 (14.781)	-0.259 (13.575)	0.991 (27.364)	.97

*(t-statistics in parentheses)

Investment Regression Coefficients (continued)

Industry	Profit	Profit Lagged	Investment Lagged	R^2
Iron and Steel	-0.000 (0.030)	0.018 (1.092)	0.951 (34.503)	.97
Non-Ferrous Metals	0.087 (7.789)	-0.059 (4.227)	0.823 (22.047)	.95
Metal Products	0.085 (6.613)	-0.080 (5.337)	0.850 (20.470)	.96
Machinery	0.140 (16.417)	-0.149 (14.064)	0.955 (33.893)	.98
Electrical Equipment	0.176 (17.338)	-0.199 (14.437)	1.029 (27.520)	.97
Transport Equipment	0.059 (3.466)	-0.024 (1.220)	0.715 (15.874)	.92
Professional Goods	0.110 (8.154)	-0.117 (7.087)	0.933 (26.176)	.98
Other Industries	0.093 (6.783)	-0.082 (4.657)	0.750 (10.170)	.95

order of .1, then β, the coefficient of q in (1) is .023. The order of magnitude of this coefficient accords well with Summers (1980) regression findings. Summers (1980) examines the response of corporate investment rates to values of q adjusted for taxes. His most preferred regression equation (Table 2, equation 5) produces a coefficient of .027. The Table suggest quite large costs of adjustment and, therefore, slower rates of wage convergence from those simulated above. The .023 coefficient implies that a 50 percent increase in stock market values would generate less than a 2 percent increase in the industry's investment rate. In addition, steady state adjustment costs equal almost 40 percent of total investment expenditures when β is .023. The empirical evidence of large adjustment costs implies that our static expectations model should be a fairly good approximation to the rational expectations model. In the limit as adjustment costs become infinite the two models will yield identical results. The advantage of the static expectations simulation model is that its computer costs are significantly less than those of the rational expectations model.

The Effect of International Wage Differentials on International Investment

Given a set of international commodity prices the model presented in Section II suggests that differences in q's across countries for the same industry should reflect international differences in wage rates.

Under the myopic expectations assumption q equals:

$$(4) \qquad q = \frac{\pi}{rK}$$

π/K is the marginal revenue product of capital. For an industry that hires labor competitively, π/K can be related to the industry's wage rate, w, according to the factor price frontier. For example, in the case of an industry with Cobb-Douglas technology and capital coefficient of α,

$$(5) \qquad \frac{\pi}{K} = \frac{\alpha}{1-\alpha}\left((1-\alpha)P\right)^{1/\alpha} w^{\alpha-1/\alpha}$$

Equations (4) and (5) suggest a cross-country regression of investment rates on international wage rates. Since our data set does not include industry specific capital stocks we could not directly run investment rates (investment divided by initial capital stocks) against international wage rates. In addition there is no transformation of the equation such as in (3) that generates a simple linear relationship between the variables in our data set. In the absence of a satisfactory specification, we experimented with several ad hoc time series specifications. The share of world investment in industry i placed in country j was related to the country's lagged investment share and the country's relative wage. Other regressions related the logarithm of investment to its lagged value as well as to the logarithm of the wage.

The results of these ad hoc specifications were quite disappointing. For virtually all industries the wage variable coefficients were both the wrong sign and very significant. Cross-country differences in wage rates may be proxying for other unmeasurable factors that influence investment such as country's degree of political stability. There is also a strong presumption that international differences in true wages are miss-measured; our data set does not permit us to control for the quality in terms of education and experience of workers across countries. Hence, what appears to be a high relative U.S. wage could in fact be a low relative wage per effective worker once account is taken of the amount of human capital embodied in the typical U.S. worker.

Determinants of Industrial Labor Demand

The adjustment cost model of Section II assumes that capital is relatively immobile in the short run. An obvious implication of this assumption is that an industry's demand for labor depends on its capital stock in place as well as the wages it has to pay. In Table XIV we test this proposition by running cross country regressions of industrial labor demand for the year 1977. The measure of capital in each industry in each country for 1977 was derived by summing the net amount of capital in 1977 that resulted from real investment flows during the period 1967 to 1977. A 5 percent rate of depreciation was used in the calculations. These capital stock figures clearly contain measurement error. This perpetual inventory method of computing 1977 capital stocks takes the benchmark values of capital stocks in 1967 to be zero, which is obviously untrue. However, in the absence of such benchmark data, the alternative is to use our "noisy" measure of the capital stock as in Table XIV or to relate labor demand to investment flows. We tried both procedures.

The first regression procedure which is described in Table XIV worked remarkably well. Despite the errors in variable problems, all 19 industries' capital coefficients are highly significant and positive. The variables in the regression are measured in logarithms. The fact that all of the capital stock coefficients are close to unity lends support to the choice of the Cobb-Douglas production function in the simulation models, since the Cobb-Douglas function exhibits unity demand elasticities with respect to the level of capital. While the wage coefficients are smaller than those suggested by the Cobb-Douglas specification (a coefficient of approximately -3), 18 of the 19 coefficients are significantly negative. Holding capital stocks and world relative prices constant, countries with higher wage rates exhibit smaller demands for labor than countries with low wage rates.

The second regression procedure involved relating annual industrial labor demands to current and past levels of investment. The relationship between current labor demand and current and lagged investment and wages implied by the logrithmic labor demand equation of Table XII is highly non-linear. Non-linear least squares was used to estimate the elasticities of labor demand with respect to capital and wages with the annual investment and wage data. The results were quite poor. While the wage coefficients tended to exhibit negative signs and were of similar magnitude to those of Table XIV, the estimated capital stock elasticities were positive, but quite small, of the order of .10, for all industries.

In addition to these attempts to relate annual labor demand to investment flows, a series of ad hoc regressions were tried. For example, the logrithm of labor demand was regressed on its lagged value and the current and lagged values of the logrithms of investment and wages. While exhibiting the correct sign, the investment coefficients were quite small in magnitude.

To summarize these empirical results, for those specifications suggested by the model that could be addressed in a straightforward manner with the data available, the results are highly supportive of the assumptions underlying the model: international investment responds to international differences in profitability, the industrial employment of labor depends on the industrial allocations of the capital stock, and labor demands are negatively related to national wage levels.

Table XIV

1977 Cross Country Industry Labor

Demand Regressions*

Industry	Capital Stock	Wages	R^2
311 Food Products	1.073 (21.459)	-0.627 (6.986)	.96
313 Beverages	0.921 (17.246)	-0.651 (4.745)	.95
314 Tobacco	0.842 (14.681)	-0.553 (4.196)	.92
321 Textiles	1.117 (21.522)	-0.469 (3.388)	.96
322 Wearing Apparel	1.034 (20.378)	-6.446 (6.446)	.95
324 Footwear	1.050 (11.403)	-0.518 (2.450)	.87
33A Wood/Furniture Products	1.005 (16.000)	-0.618 (4.631)	.94
341 Paper and Products	0.895 (16.150)	-0.563 (3.635)	.94
35A Indust/Other Chemicals	0.908 (23.104)	-0.734 (6.118)	.97
355 Rubber Products	0.997 (25.474)	-0.699 (6.016)	.97
356 Plastic Products, N.E.C.	1.143 (25.104)	-0.731 (7.649)	.97
36A Pottery/Glass Products	1.054 (19.888)	0.507 (4.590)	.95
371 Iron and Steel	0.938 (16.740)	-0.346 (1.982)	.97
362 Non-ferrous Metals	0.972 (11.674)	-0.872 (3.929)	.94

Industry	Capital Stock	Wages	R^2
381 Metal Products	1.076 (25.118)	-0.712 (7.272)	.98
382 Machinery, N.E.C.	0.935 (23.842)	-0.485 (3.751)	.98
383 Electrical Machinery	0.981 (21.489)	-0.578 (5.055)	.97
385 Professional Goods	0.905 (23.886)	-0.368 (2.843)	.98
390 Other Industries	1.008 (33.933)	-0.600 (7.462)	.99

*t statistics in parenthesis
All variables measured in logrithms

Conclusion and Ideas for Future Research

A model of international trade with costly capital stock adjustment appears capable of explaining those patterns of factor price equalization, international investment, and changes in comparative advantage that have characterized the post-war period. The model presented here, while capturing a good deal of the economics of transitional growth falls short of capturing historical reality in three important respects. First, post-war wage differentials have been substantially greater than those predicted by the model. Second, certain countries such as Germany and Japan with initially low levels of capital per worker have historically run surpluses on current account. Our model predicts current account deficits for those countries that are rapidly accumulating capital. Third, different countries appear to have permanently different savings rates. The model presented here implies that during the economic transition countries with lower than average capital labor ratios will have higher than average savings rates, but that savings rates will equalize in the long run. The Table IV figures indicate only minor convergence of international savings rates in the last two decades. Future research will address these issues in three ways. First, the model described here will be altered to allow for acquisition of and investment in technological knowledge. An optimal technology investment function will be derived that is similar to those investment functions that have been derived in the context of the acquisition of human capital. The technology investment function will have the property that countries with the least amount of technological knowledge will have the greatest incentive to accumulate such knowledge. Initial international differences in technology will permit larger simulated values of initial wage differentials.

The second shortcoming of the model, its prediction about current account balances, will be addressed by specifying government policies that are aimed at "improving" the current account. The policies will include export subsidies and taxes on the repatriation of income from capital. While improving the current account these policies are likely to reduce the welfare of domestic residents. Hence, the dynamic welfare costs of such policies will be analyzed as well.

Finally, international differences in savings rates can be analyzed by including life cycle savers as well as infinite horizon utility maximizers in the model. With such a model, one could trace out the effects of government deficit policies on current account balance and determine the impact of a foreign stimulus to demand on domestic welfare.

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